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THE CAMBRO-SILURIAN QUESTION IN MISSOURI AND ARKANSAS.

It is a remarkable fact that of all the great Mississippi basin with its area equal to more than one-third of that of the whole United States, its very center, the portion which is richest and most important of all in mineral wealth, should be the only portion which has remained geologically a veritable *terra incognita*. The region is widely known as the Ozark uplift, a broad dome which occupies the southern half of Missouri and the northern part of Arkansas. The rocks composing it form an important sequence of dolomitic and arenaceous beds which are known to lie between the horizon of the Trenton limestone and the crystalline, or Archæan, complex; and which have recently been termed by Broadhead¹ the Ozark series.

In the earlier geological reports of Missouri great prominence was given to the succession of magnesian beds. By Swallow² there were considered to be four thick limestones, separated by sandstones. They were known as the First Magnesian limestone, at top, the First or Saccharoidal sandstone, Second limestone, and so on to the Fourth Magnesian limestone at the bottom. The aggregate thickness of this "Magnesian Limestone" series was considered to be over 1200 feet. It was referred to the Calcareous division of the New York section as then understood.

Since the appearance of Swallow's report other work has been done in the region, and of recent years interest in the subject has been revived. In southeastern Missouri more attention has been directed to the Magnesian rocks than perhaps anywhere else in the Ozark uplift, and although many new facts have been obtained much additional information is necessary before satis-

¹ American Geologist, Vol. VIII, p. 33. Minneapolis, 1891.

² Geol. Sur. Missouri, 1st and 2d Ann. Repts., p. 60. Jefferson City, 1855.

factory conclusions concerning the exact geological age of the different parts of the general section can be drawn.

The igneous masses beneath the sedimentaries are known to be Archæan in age. They were subjected to prolonged degradational action; and it was upon their profoundly eroded surface that the sand and limestones were laid down during early Palæozoic times, burying to very considerable depths probably all of the old peaks and elevations. While it is true that the relations of the different sections of the region has not yet been determined with accuracy it appears evident from the data at hand that the Silurian is well represented and that a part belongs to the Cambrian.

In southeastern Missouri the Palæozoic rocks from the top of the column down to the base of the Trenton are well known. Beneath the latter there is, as first made out by Shumard, a bluish, limerock having a thickness of upwards of 100 feet, which has been regarded as the non-fossiliferous portion of the formation just mentioned. Below all this there comes the sequence of dolomites and sandstones to which reference has been made. It has further been stated that there were formerly considered to be four great limestones alternating with arenaceous beds; but of late it has come to be believed that the relations of these beds are not exactly in accordance with the views expressed at first. East of the crystalline area and trending in a broad curve northwest and southeast, a direction which is nearly at right angles to the axis of the uplift, are the oldest Palæozoic rocks whose geological age is definitely known. Immediately west of this belt of strata, which is the fossiliferous Trenton limestone and the band of similar rock but almost without fossils, is a narrow zone of what has been termed the First Magnesian limestone, and then in a somewhat broader belt the First or Saccharoidal sandstone. A short time ago¹ it was suggested that the latter probably rested unconformably upon the strata beneath; and more recently Winslow² has reported from the vicinity of

¹KEYES: Missouri Geol. Sur., Vol. IV, p. 35. Jefferson City, 1894.

²Missouri Geol. Sur., Vol. VI, p. 356. Jefferson City, 1895.

Pacific, forty miles west of St. Louis and elsewhere, unmistakable evidences of a marked unconformity at this horizon. Now the Magnesian limestones and sandstones of the crystalline area, are, according to the best accounts, at a geological level considerably below the Saccharoidal sandstone. Regarding the age of the rocks Broadhead,¹ who has been in the region more than any one else perhaps, is inclined to assign a large part of them to the Cambrian. Lately, Walcott² in his correlation essay on the Cambrian of North America, has summed up all that is known on the subject and has colored on his map of the continent as Cambrian all of the sedimentaries of the crystalline district of Missouri.

The correlation of the Magnesian limestone of southern Missouri has been almost entirely upon very meager stratigraphical grounds. From one end of the broad uplift to the other, wherever the rocks of this series are open to view, there has been found up to the present time a great paucity of fossil forms. Not only are the rocks almost devoid of the ordinary faunal means by which the different terranes may be determined with precision, but the organic remains thus far secured are so poorly preserved that they are largely worthless for systematic purposes. Further, it is quite remarkable that of all the forms obtained from these rocks there have been none which have been identified with certainty with species described from other districts. In every case where specific comparisons have been made more or less doubt has always been expressed concerning the actual identity of the species referred to. Of the many fossils mentioned in connection with the various allusions to, or descriptions of, the region, few of the references have been more than generic. In a recent critical review³ of the fossils of Missouri, collections made by different individuals from the Magnesian limestones were examined. The material proved to be so fragmentary on the whole, and the exact or even approximate horizons where the particular forms were obtained so poorly determined that

¹ American Geologist, Vol. III, p. 7. Minneapolis, 1889.

² U. S. Geol. Sur., Bulletin 81. Washington, 1891.

³ Missouri Geol. Sur., Vols. IV and V. Jefferson City, 1894.

practically nothing could be inferred regarding the relations to one another of the fossil-bearing horizons in the different localities. Many of the fossils imperfectly preserved, as most of them were, appeared to be undoubted Silurian forms, while others possessed a very decided Cambrian aspect, but in no case were the faunas extensive enough to warrant an exact arrangement of the succession. All the fossils that have been mentioned or recorded from the limestones of Missouri have recently been tabulated by Winslow & Robertson.¹ By these tables and the accompanying paragraphs of explanation the utterly intrustworthy character of the faunal evidence thus far obtained for separating the Ozark series of Missouri into its proper terranes is admirably shown. Of the total of 151 entries more than one-half of the forms are duplicated; only twenty-two are specifically different and of this number but half a dozen are referred to species occurring in other localities. Although considerable information concerning the geology of the district has been obtained there yet remains to be done much detailed work. What is true in regard to the fossils in the strata of this region is equally applicable to those found in other portions of the uplift, except that in most other localities they are of even rarer occurrence.

The Silurian rocks of well determined age which lie above the lower part of Ozark series of Magnesian limestones occur chiefly in the eastern part of the region. They are best exposed along the Mississippi river between St. Louis and the mouth of the Ohio, and include the Trenton limestone, the Hudson shales and certain Upper Silurian limestones. Farther south in northern Arkansas strata thought by Williams² to represent a part of this sequence are reported. But it is beneath the Trenton in the eastern portion of the uplift that the difficulty comes in attempting to fix the geological age of the strata.

As explicitly stated elsewhere³ the Ozark series of Broadhead includes both Silurian and Cambrian, instead of the latter alone,

¹ Missouri Geol. Sur., Vol. VI, pp. 380-385. Jefferson City, 1895.

² Arkansas Geol. Sur., Ann. Rep. 1890, p. 108. Little Rock, 1893.

³ KEYES: Missouri Geol. Sur., Vol. IV. Jefferson City, 1894.

as was finally thought by the author of the name. The limestones of the series cover a very large part of the Ozark region, and it is quite probable that a very considerable proportion of them will be found to be Silurian not only in Missouri but in Arkansas. In the Batesville region Trenton fossils have been recognized by Williams,¹ and beneath the strata containing them are Magnesian limestones and sandstones which are referred to the Calciferos. "Only the upper members, however, are such. The larger part remain to be studied. Below them and exposed to the north is a series which according to Branner pass into Missouri."² Farther to the west in the Ouachita district the novaculite rocks are said to be largely Silurian. As evidence a number of Graptolites have been described and a few molluscan remains recognized.

The nearest region presenting rocks of similar age and lithological characters, one which has been, moreover, thoroughly investigated and with which the Missouri strata are to be compared, is in northeastern Iowa and the adjacent portions of adjoining states. It is therefore the Cambro-Silurian section of the Upper Mississippi that must serve as a standard of comparison for the Missouri rocks under consideration, and with which detailed correlations must be made. This fact necessarily has great weight in all attempts to correlate the rocks of the two districts. In the absence of faunal evidence that was at all satisfactory; with so small a proportion, in the Mississippi valley, of the Silurian existing below the Trenton which is an horizon clearly defined in all parts of the basin; with a thickness in Missouri of Magnesian and Saccharoidal sandstone below the Trenton nearly twice as great as in Iowa between that formation and the top of the Cambrian; with the evidence of a marked line of unconformity at the base of the First sandstone; and with a considerable sequence of limestones and sandstones beneath the physical break mentioned, the evidence appeared at the time of the recent review of the geological formations of Missouri amply sufficient for regard-

¹ Arkansas Geol. Sur., Ann. Rep., 1890, Vol. I, p. 112. Little Rock, 1891.

² Ibid., p. 116.

ing, provisionally at least, the Magnesian limestone series below the Saccharoidal sandstone as Cambrian. The facts requisite to a final conclusion as to whether or not this line is the correct divisional one must be derived from a consideration of abundant fossils after a careful stratigraphic connection of the various sections has been made. In making a comparison of the Magnesian series with the Cambro-Silurian of Iowa and Minnesota it may be noted that according to the recent work of Hall and Sardeson¹ the line between the Cambrian and Ordovician (Lower Silurian) is carried up to the base of the St. Peter sandstone, where a very distinct faunal break occurs. The Middle Cambrian is also recognized. This narrows down the space between the Cambrian and the Trenton limestone in that region to still smaller dimensions, so that if the inference is correct only a thin sandstone now intervenes. If, further, the correlation by Worthen² of the St. Peter formation of northern Illinois and the sandstone at Cap-au-Grès, near the mouth of the Illinois river, and that sandstone with the Saccharoidal of Missouri is right, there is added further weight to the existence of the unconformity at the base of the latter.

Regarding the age and history of the Ozark uplift much might be said. Since it is quite probable that the Archæan peaks of southeastern Missouri formed the first land in the region to appear above the waters of the continental ocean it has been the general opinion among those who have worked in the district that the crystallines remained above sea level as an archipelago from pre-Cambrian times until the close of the Palæozoic when all the area around became a land surface. This has led to the inference that the existing geographic features are very old. But the validity of these conclusions is not only very questionable but it is manifest that the present features of the Ozarks are essentially modern.

It is probable that from Archæan times the region has been one of constant oscillation, for the most part slight, perhaps, but at

¹ Bul. Geol. Soc. America, Vol. VI, p. 170. Rochester, 1865.

² Geol. Sur. Illinois, Vol. I, p. 150. Springfield, 1866.

certain periods quite marked. Some of these changes in elevation are clearly defined, but the records of most of them are now obliterated. One of the most notable results of the warping of the lithosphere in this district was at the beginning of Palæozoic time, when the crystalline complex was subjected to profound subaërial erosion. Minor changes of level are also recorded. Another period of notable uprising was during Devonian times. A third was towards the close of the Lower Carboniferous, after the deposition of the St. Louis strata. Still another was one which closed Palæozoic deposition in the continental interior. Unconformities of greater or less prominence record these episodes in the geological history of the region. In post-Palæozoic times the oscillations of level were manifestly not less marked than in the earlier periods. The most noteworthy perhaps was the gain of the land after the protracted submergence recorded by the Cretaceous. It was probably at this time that the forces of compression were felt most and that the warping and folding was more intense than at any other period in the history of crustal movement in the Ozark region. Moreover, it is to this period that the intrusions of igneous rocks along the southern or coastal margin of the uplift in central Arkansas are assigned. Evidences of a subsequent lower level of the land surface are manifested in the peculiarities of the topographic forms in the plateau district and in the relatively uniform evenness of the upland plain. Conclusions deduced from glacial investigations point to a depression in very late geological times of the surface of the continental interior below its present position. This carries with it the inference that since the close of the Tertiary elevation has taken place. This is clearly indicated in the youthful topography now existing along the borders of the uplift. The watercourses have cut profound valleys in the general upland plain, and now flow in canyon-like trenches which are ever deepening as the streams recede from their sources. Erosion is now going on vigorously. The rivers are carrying away the débris from their steep-sided banks as fast as formed, and are rapidly cutting lower and lower their confined and contracted

channels, while their deepening gorges are being constantly carried back towards the crest of the great divide. The cycle of the last movement is not yet ended; and the change in level of the region is probably going on now as rapidly as it ever has in past geological time, and as rapidly as oscillations of the land surface usually take place.

From the foregoing it may be inferred that since the original deposition of the Ozark series, the rocks have been profoundly eroded, and that the later formations which are known to have covered in great part the Magnesian beds of the uplift have been almost entirely removed during the periods of emergence.

As yet, then, the exact geological age of the different parts of the Ozark series is not determined, but the horizons where the proper lines should be drawn are foreshadowed, and with the passage of another season it is believed that the question, both faunally and stratigraphically, will be satisfactorily settled.

CHARLES ROLLIN KEYES.